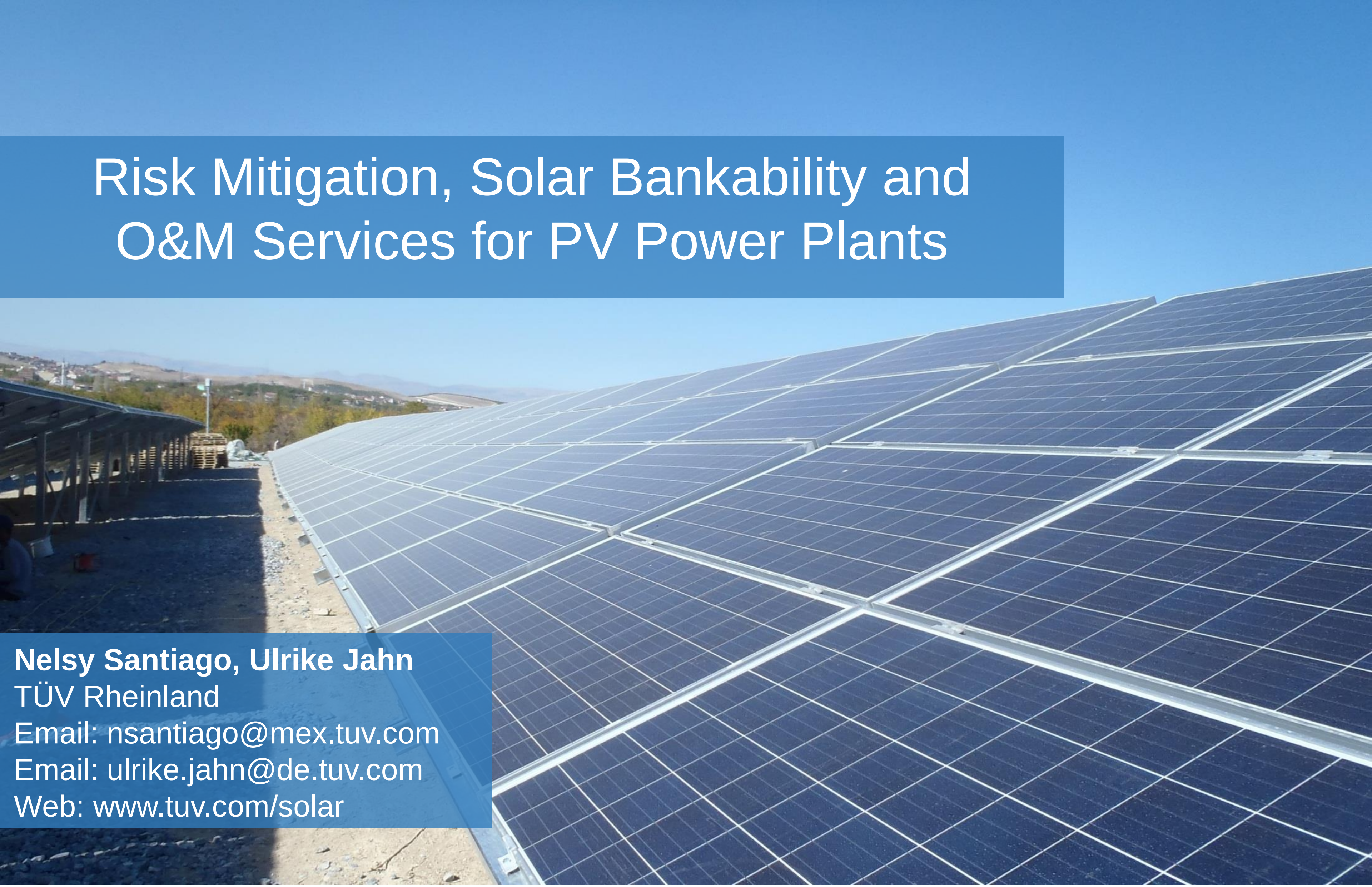

Risk Mitigation, Solar Bankability and O&M Services for PV Power Plants

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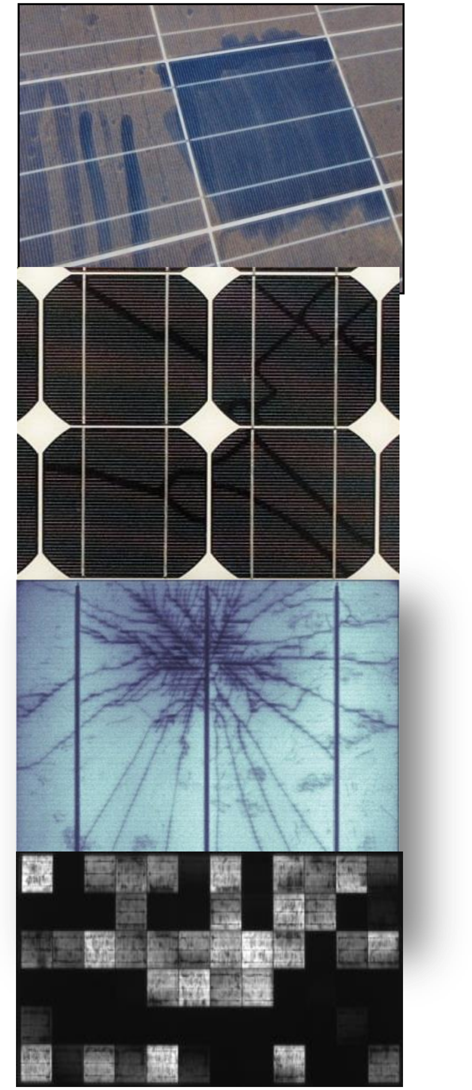

1. Overview

- **Solar bankability** is an active quality management process where all stakeholder in the approval process of a PV project attempt to identify potential legal, technical and economical risks through the entire project lifecycle.
- These risks need to quantitatively and qualitatively assesses, managed and controlled.
- Despite a wide overlap in this quality management process, the focus and the assessment criteria will vary whether the stakeholder represents an investor, a bank, an insurance or a regulatory body.

1. Overview

Stakeholder bankability assessment	Investor „Investibility“	Bank „Bankability“	Insurance „Insurability“	Regulatory Body „Efficiency of infrastructure“	
Check list/ due diligence	Legal	Technical	Economical		
Project life cycle	Development	Design	Installations	Operations	Decommis-sioning
Contracting parties	Building/ site owner	Project developer	EPC/ installer	O&M	Decommis-sioning
Component suppliers	Module	Inverter	Balance of system	Monitoring	

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2. Technical Risk Identification

Project Development | Assessment of PV Plants

	Product testing	Planning	Transportation / installation	O&M	Decommissioning
Modules	….	….	….	….	….
Inverter					
Mounting st					
Connection boxes					
Cabling					
Potential eq grounding, L					
Weather sta communicat					
Infrastructur influence					
Storage syst					
Miscellaneo					

Product testing	Planning	Transportation / installation	O&M	Decommissioning
• Improper Insulation • Incorrect cell soldering • Undersized bypass diode • Junction box adhesion • Delamination • Arcing spots on the module • Visually detectable hot spots • Unclear initial degradation • Uncertified components or production line • Unsuitable/ uncertified Bill of Materials (BOM) • Incorrect power rating (flash test issue)	• Soiling • Shadow diagram • Modules mismatch • Modules not certified • Flash report not available or incorrect • Special climatic conditions not considered (salt corrosion, ammonia, ...) • Incorrect assumptions of module degradation, light induced degradation unclear • Module quality unclear (lamination, soldering) • Simulation parameters (low irradiance, temperature….) unclear, missing PAN files	• Module mishandling (glass breakage) • Module mishandling (cell breakage) • Module mishandling (defective backsheet) • Incorrect connection of modules • Bad wiring without fasteners	• Hotspot • Glass breakage • Soiling • Shading • Snail tracks • Cell cracks • PID • Failure bypass diode and junction box • Corrosion in the junction box • Theft of modules • Delamination • Module degradation • Slow reaction time for warranty claims, vague or inappropriate definition of procedure for warranty claims • Spare modules no longer available, costly string reconfiguration	• Undefined product recycling procedure

Source: Solar Bankability

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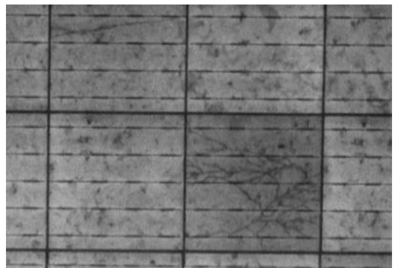
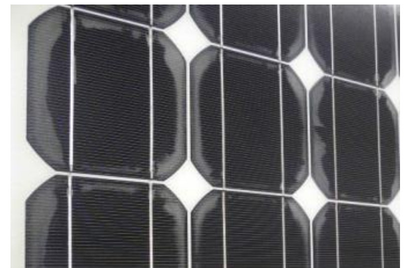
Examples for PV module failures

Glass breakage



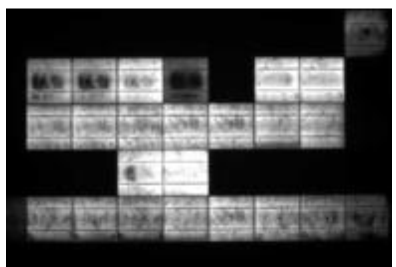
Cell cracks



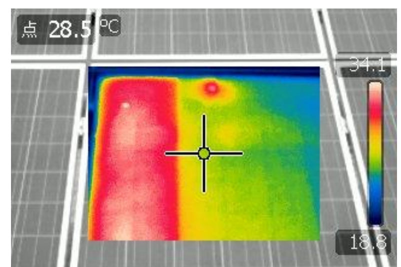
Delamination

Frame breakage

Junction box failure



Potential induced degradation



Bypass diode failure

Safety issues

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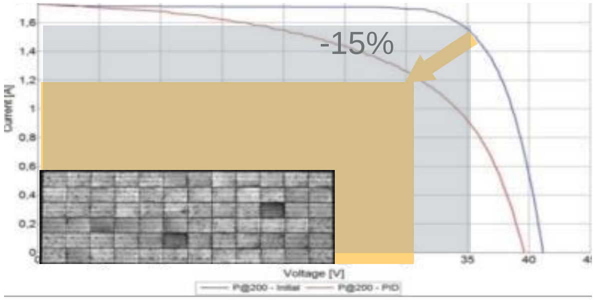
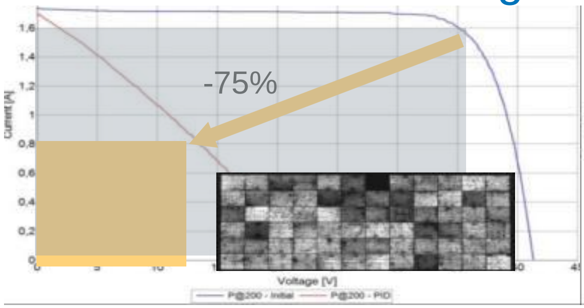
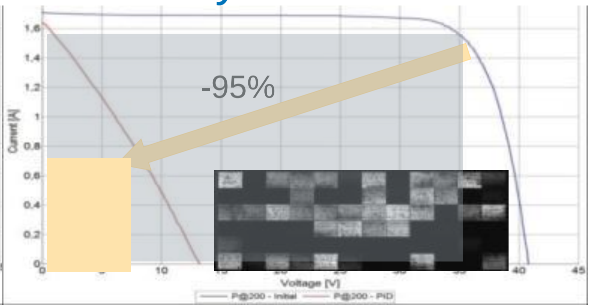
Examples for PV module failures: Potential Induced Degradation

- Performance killer number one: potential induced degradation (PID)
  (occurs in cases of high voltage, sensitive module/material combinations and damp environments – e.g. caused by condensation, high humidity)
- Reversible process through grounding or counter-potential (investments required)

Test results of PID tests of PV modules from a large-scale PV system







! Knowledge of PID sensitivity of used PV modules is necessary.
All material combinations of a module type must be considered to declare it PID-free!

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3. Assessment of Technical Risks
Cost Priority Number (CPN) Approach

a) Economic impact due to downtime and/or power loss (kWh to Euros)
- Failures might cause downtime or % in power loss
- Time is from failure to repair/substitution and should include: time to detection, response time, repair/substitution time
- Failures at component level might affect other components (e.g. module failure might bring down the whole string)

→ Income reduction
Savings reduction

C_{loss}

+

C_{fix}

b) Economic impact due to repair/substitution costs (Euros)
- Cost of detection (field inspection, indoor measurements, etc)
- Cost of transportation of component
- Cost of labour (linked to downtime)
- Cost of repair/substitution

→ Increase in maintenance costs
Reduction of reserves

O&M

- **Risks to which we can assign a Cost Priority Number CPN: CPN in [€/kWp/year] (e.g. module and inverter failure during O&M)**

→ Impact on cash flow

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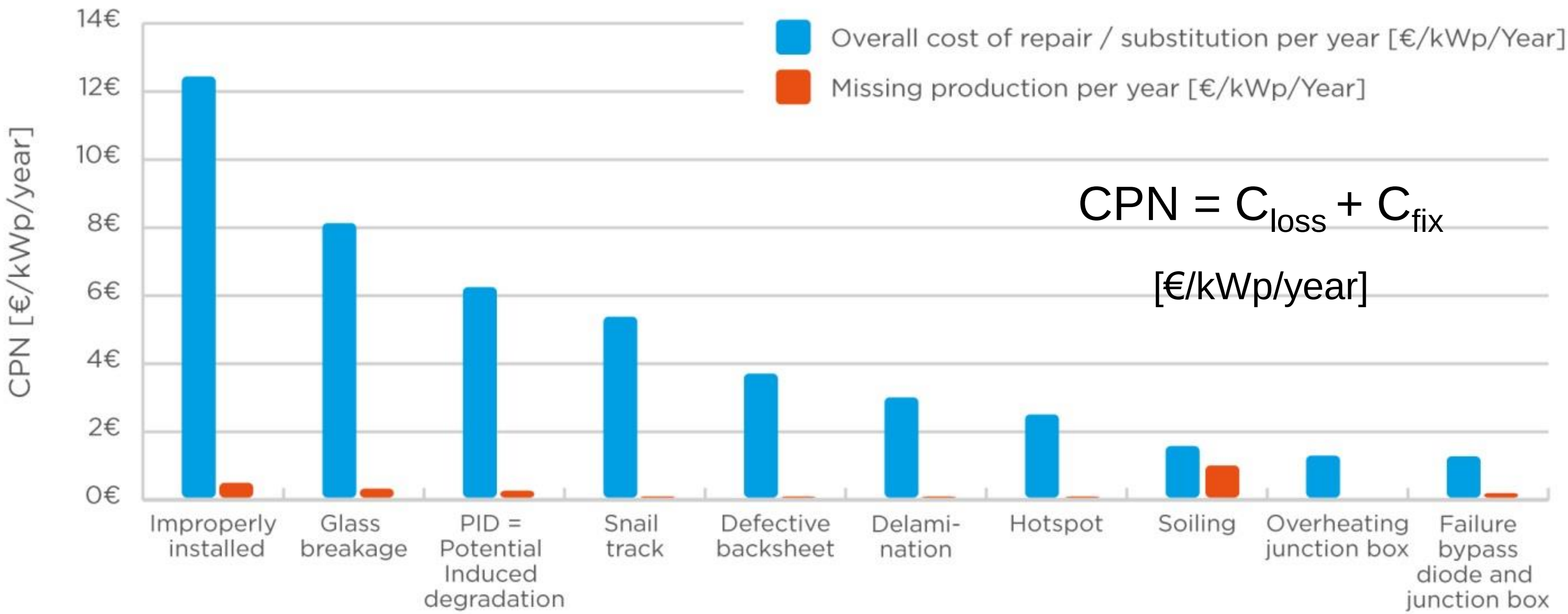
3. Assessent of Technical Risks
CPN Approach – PV Modules



- Highest risk consists of a group of installation failures (mishandling, connection failures, missing fixation, etc.)
- Variety of failures detected by different techniques (VI, IR, EL, IV-Curves)

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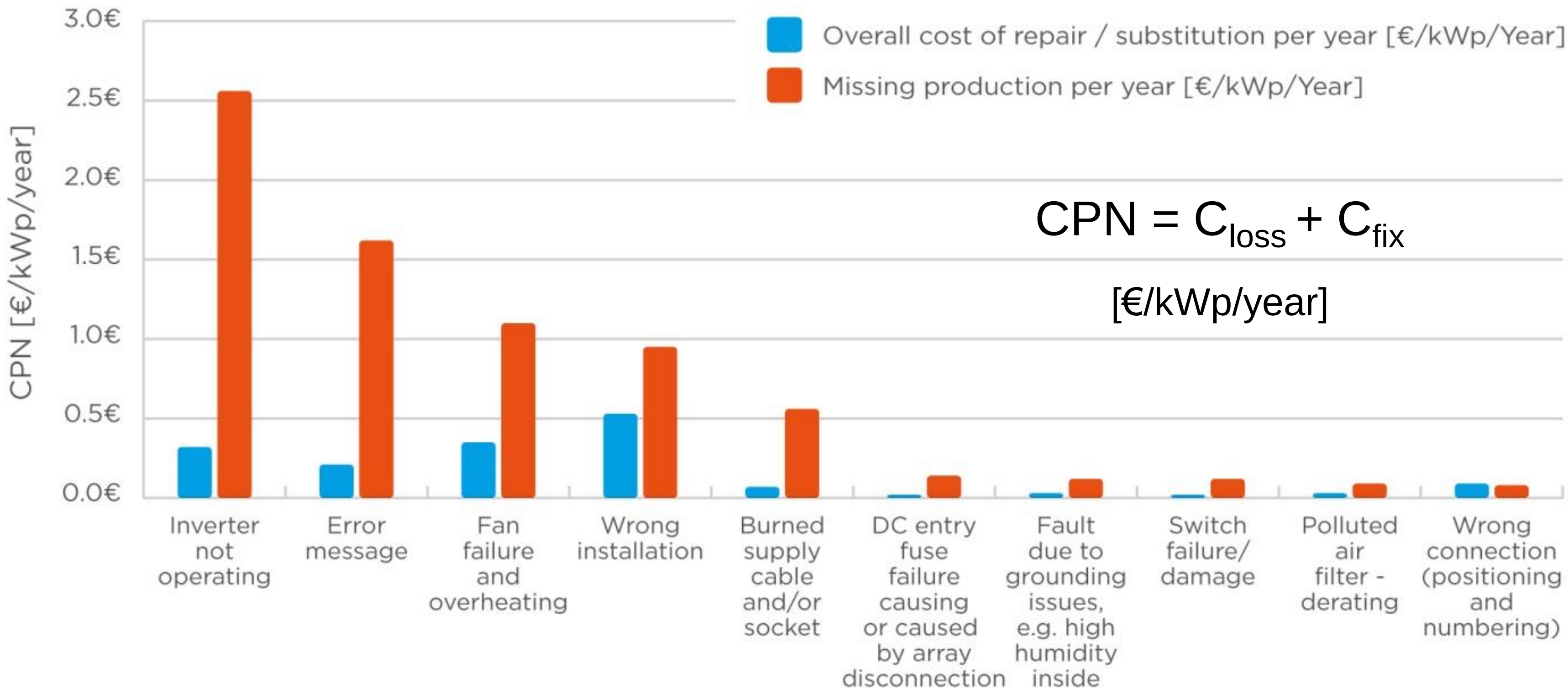
3. Assessment of Technical Risks

CPN Approach – Inverter



- Highest risk for accumulation of installation faults and overheating of ventilation.

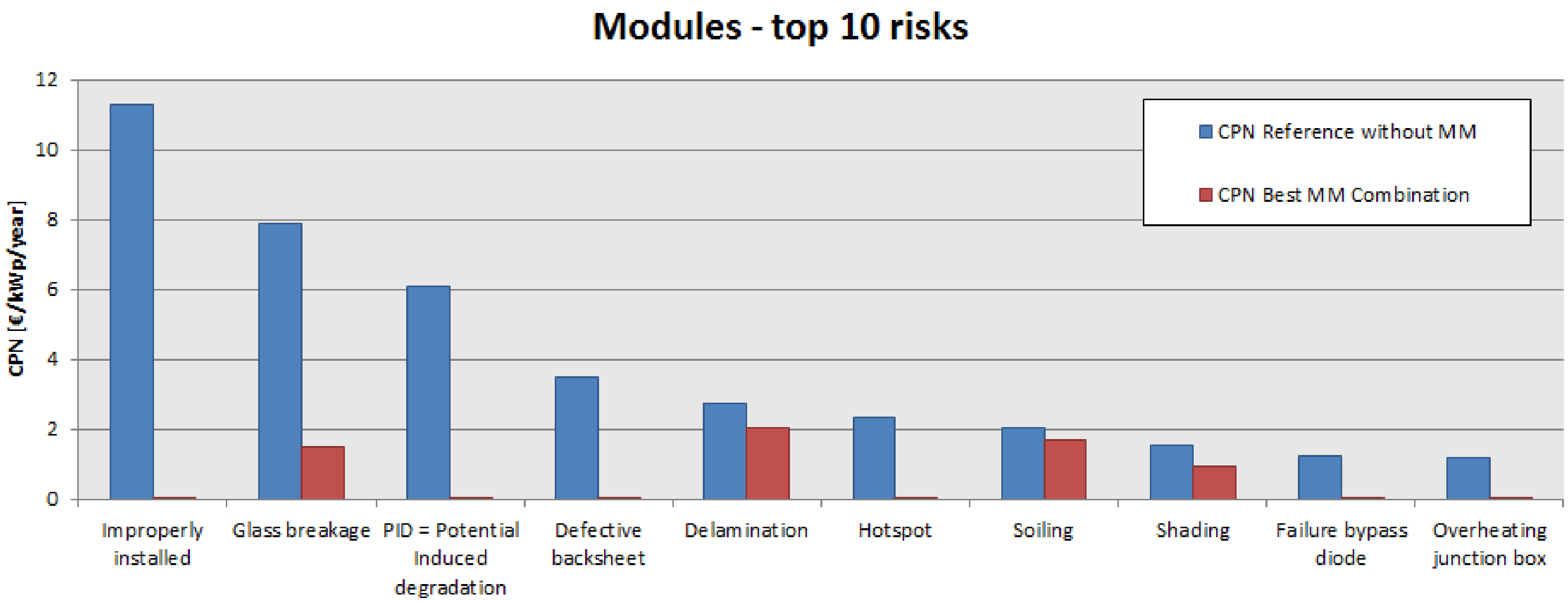
4. Mitigation of Technical Risks

Mitigation Measures (MM)

Mitigation Measure	Affected Parameter	Risk Mitigation Factor
Component testing – PV modules	number of failures	α
Design review + construction monitoring	number of failures	α
Qualification of EPC	number of failures	α
Advanced monitoring system	time to detection	β
Basic monitoring system	time to detection	β
Advanced inspection	time to detection	β
Visual inspection	time to detection	β
Spare part management	time to repair/substitution	γ

4. Mitigation of Technical Risks
CPN Results – Best combination of MM

Component testing	Design review + construction monitoring	Qualification of EPC	Advanced monitoring system	Basic Monitoring system	Advanced Inspection	Visual Inspection	Spare part management
1	1	1	0	0	0	1	0



- Impact of Applied Mitigation Measures on and Ranking of CPN

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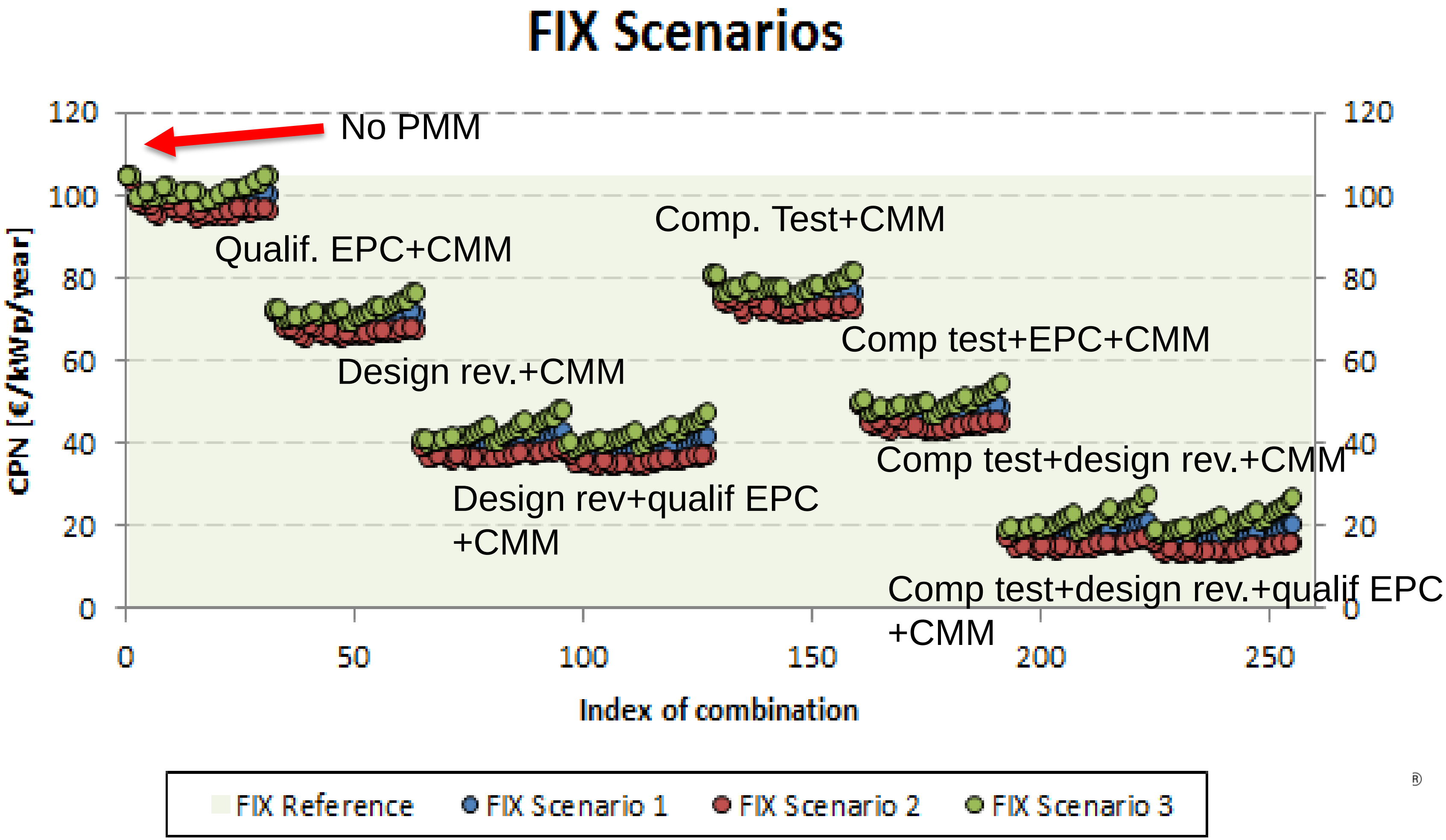
4. Mitigation of Technical Risks
Impact of Applied Mitigation Measures

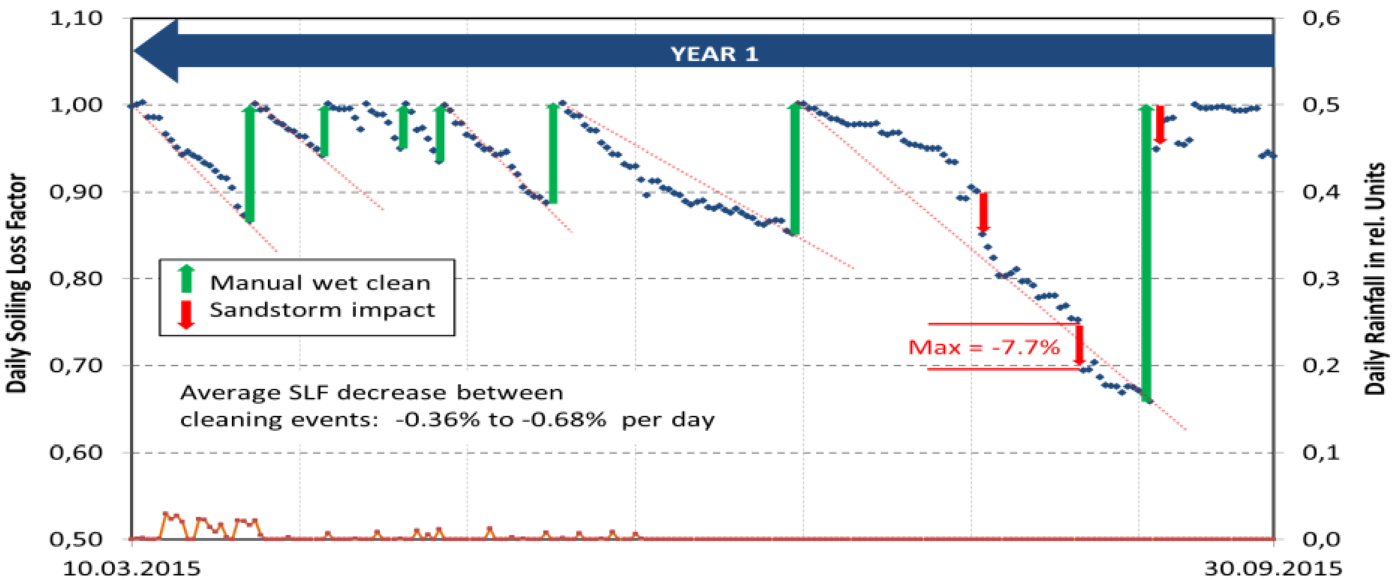
New CPN results $C_{fix,mit}$ of mitigation measure combinations for different cost scenarios:
Preventive measures (PMM) have higher impact than corrective measures (CMM).



5. Case Studies of Risk Assessments

Field Testing and Soiling Simulation

Example: Soiling @ Thuwal/Saudi-Arabia



- Yield losses > 5 % within 1 week are possible

!

- Site specific cleaning concept is required

- High ambient dust concentration ⇨ Average daily percent decrease of - 0.5 %
- Dust storm ⇨ Max. soiling loss factor (SLF) → change per day = - 7.7 %

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5. Risk Assessment - Wrap Up

1. Large utility-scale PV projects under government tender schemes face severe price pressure. A **quality management programme** should ensure the technical reliability and financial viability of the PV projects.

2. A professional **risk management strategy** as suggested in this project should become integral part of each PV investment.

3. The risk management function should be hierarchically independent and can be provided by qualified in-house or **external third party experts.**

6. Supply Chain Quality Assurance Services

Along each procurement step

	Sourcing	Production	Post-Production
At the Factory	▪ Factory audits	▪ Pre-production inspection ▪ DuPro inspection	▪ Pre-shipment inspection ▪ Loading supervision
	In the TÜV Rheinland Laboratory	▪ Reference module creation ▪ Reliability Tests	▪ Fast random verification test ▪ Final product control test
		On the Construction Site	▪ Post-shipment inspection

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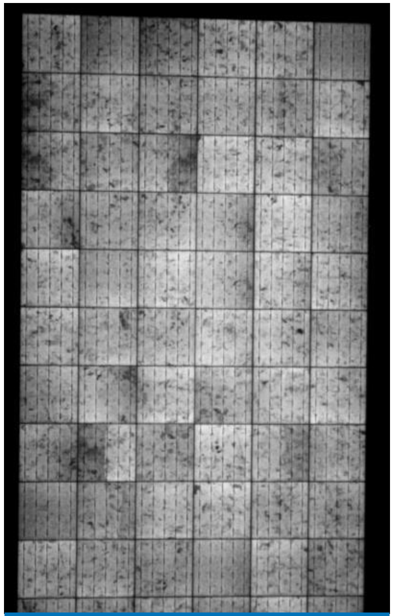
6. Supply Chain Quality Assurance Services

Fast random verification tests at third party laboratory

Visual Inspection

Power Measurement



Electroluminescence

Safety tests

@ TÜV Rheinland Laboratory

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6. Our Service at all Stages of PV Power Plant Investment

During Planning

- Site feasibility
- Tender development
- Product qualification
- Vendor qualification/ bankability services
- Technical DD
- Specific yield prediction
- Risk assessment
- Financial sensitivity analysis

Development, Planning | Commissioning | Operation and Maintenance

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Our Service at all Stages of PV Power Plant Investment

During construction

- Pre-shipment testing and inspections
- Factory acceptance testing
- Construction monitoring & supervision
- Cost review
- Punch list
- Mechanical completion inspection
- Performance acceptance testing & verification
- Provisional and final acceptance report
- O&M concept, contract & manual review

Design → Commissioning → Operation and Maintenance

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6. Our Service at all Stages of PV Power Plant Investment

After construction

- Performance Ratio (PR) verification & Independent energy analysis
- Periodic inspection
- First year capacity test
- Warranty inspections
- Technical Due Dilligence
- Module status (quality) analysis
- Performance optimization
- Monitoring, data analysis & sensor calibration
- Arbitration services

Design → Commissioning → **Operation and Maintenance**

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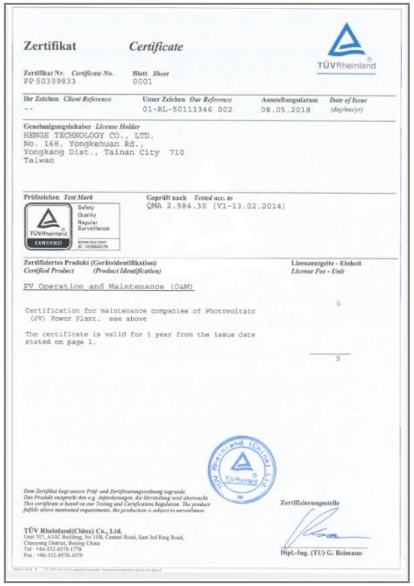
6. PV Power Plant O&M Contractor Certification

Application

Submission

- Application Form
- ISO 9001Certificate
- List of O&M service
- List of PVPP under service
- Business license (initial application)



Zertifikat *Certificate*

Zertifikat Nr. *Certificate No.* PP 50399833 — Blatt *Sheet* 0001

Ihr Zeichen *Client Reference* -- | Unser Zeichen *Our Reference* 01-RL-50111346 002 | Ausstellungsdatum *Date of Issue* 08.05.2018 (day/mo/yr)

Genehmigungsinhaber *License Holder*
HENGS TECHNOLOGY CO., LTD.
No. 168, Yongkehuan Rd.,
Yongkang Dist., Tainan City 710
Taiwan

Prüfzeichen *Test Mark*: TÜVRheinland CERTIFIED — Safety, Quality, Regular Surveillance

Geprüft nach *Tested acc. to* QMA 2.584.30 (V1-13.02.2014)

Zertifiziertes Produkt (Geräteidentifikation) *Certified Product (Product Identification)* — Lizenzentgelte - Einheit *License Fee - Unit*

PV Operation and Maintenance (O&M)

Certification for maintenance companies of Photovoltaic (PV) Power Plant. see above — 5

The certificate is valid for 1 year from the issue date stated on page 1.

5

Dem Zertifikat liegt unsere Prüf- und Zertifizierungsordnung zugrunde. Das Produkt entspricht den o.g. Anforderungen, die Herstellung wird überwacht. This certificate is based on our Testing and Certification Regulation. The product fulfils above mentioned requirements, the production is subject to surveillance.

TÜV Rheinland(China) Co., Ltd.
Unit 707, AVIC Building, No 10B, Central Road, East 3rd Ring Road, Chaoyang District, Beijing China

Zertifizierungsstelle

Dipl.-Ing. (TU) G. Reimann

Step	
Step 1	Application
Step 2	Creation of audit plan and quotation
Step 3	▪ Documentation review ▪ Onsite O&M audit
Step 4	Evaluation of the audit results
Step 5	Re-audit / Review after correction
Step 6	Reporting and certificate application
Step 7	Certification
Step 8	Annual audit

6 month lead time

at least **2** PVPP units

2 months correction period

3 years of validity

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6. PV Power Plant O&M Contractor Certification

TÜV Rheinland O&M Contractor Certification

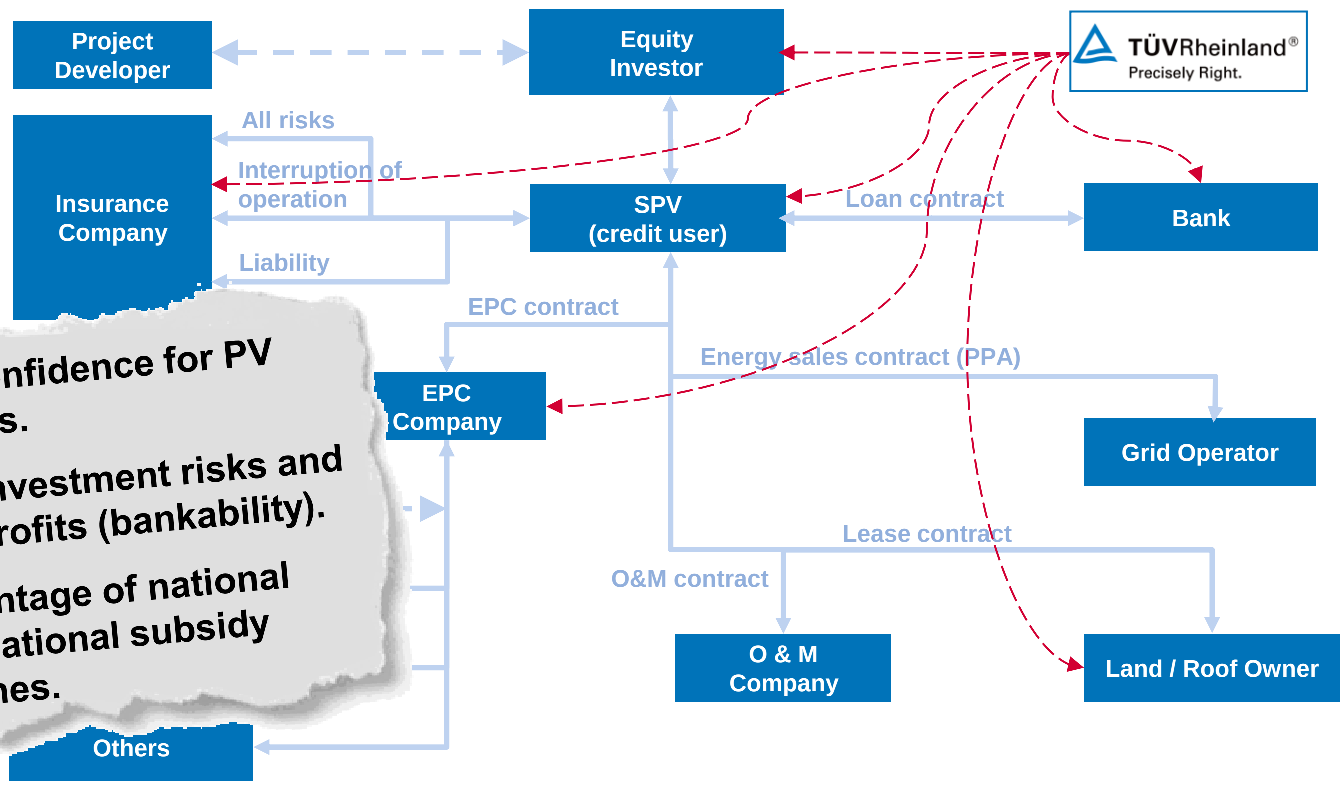
Index	General Requirement	Operation	Maintenance	Spare Parts Management	Security, EHS and PPE	Contract Fulfillment	Local Requirement
Criteria	Service Definition	DMS	Preventative Maintenance	Responsibility	Site Security	Conformity	Legal
	Structure	Supervision and Control	Corrective Maintenance	Insurance management	Staff/PVPP insurance	Client Satisfaction	Industrial
	Personnel Qualification	Grid Code Compliance	Extra Maintenance	Stock level	EHS	Performance Evaluation	Others
	Confidentiality	Performance Forecast	Additional Maintenance	Storage	PPE		
	QM documentation*	Change Management					
		Reporting					
		Optimization					
Standards	ISO 9001 IEC 63049	IEC 61724 series	IEC 62446 series		IEC 61724 Series		

7 indexes

30 main criteria

100^+ sub-criteria

6. Supply Chain Services for all Stakeholders of PV Plant Investments



- Increase confidence for PV investments.
- Minimize investment risks and increase profits (bankability).
- Take advantage of national and international subsidy programmes.

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thank you
danke
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teşekkür ederim
gracias
спасибо
Баярлалаа
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mersi
kia ora
barka
welalin
tack
spas
dank je
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matondo
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